Uncertainty quantification in the simulation of traffic emissions

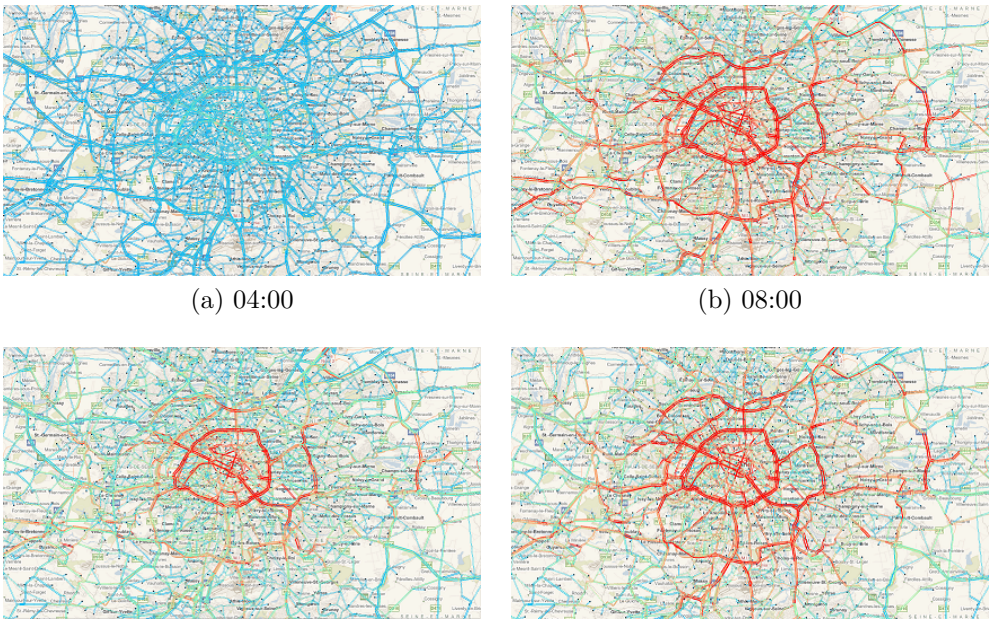
PhD thesis
July 2014

1 Context and objectives

In their move toward more efficient use of infrastructures, communication and services, cities need better tools for **decision making**, especially for environmental management. These tools should rely on in situ **observations** and **numerical simulations**, and optimally merge these two information sources for **analysis** and **forecast**. A key and challenging point is to always provide **uncertainty estimation** along with the analyses and forecasts. The PhD offer precisely deals with the development of methods for uncertainty quantification, with application to traffic simulation at urban scale.

The position will be funded by the project ESTIMAIR which aims to propagate uncertainties in traffic and air quality simulations at urban scale. The PhD work will address the propagation of uncertainties in the traffic and emission models, and the proposed methods will be implemented on the air quality application by partners of the project. The PhD work will therefore be a key component of the project. The project ESTIMAIR involves

- INRIA (leader), the French national institute for research in computer science and control;
- École des Ponts ParisTech, a top French "Grande École";
- NUMTECH, the French leading company for air quality simulation at urban scale;
- LMFA: research laboratory on fluid mechanics at École centrale de Lyon.



(a) 04:00 (b) 08:00

(c) 12:00 (d) 18:00

Figure 1: Emissions of carbon monoxide over Paris region, as computed using the dynamic traffic model LADTA for different hours in the day. The objective of the PhD work is to quantify the uncertainties of such results.

2 Anticipated work

The work will be carried out with the **dynamic traffic model** LADTA, developed at École des Ponts ParisTech by the laboratory LVMT. The emission model is implemented on top of it, using the COPERT 4 formulae from the European Environment Agency.

The dynamic model LADTA assigns the traffic in all roads of a given network in order to meet the demand while satisfying the constraints on the roads capacities. See Figure 1. In many traffic models, the optimal distribution of the vehicles is formulated as a static problem, leading to a classical optimization problem. In contrast, LADTA deals with a more accurate but challenging dynamic formulation (involving variational inequalities). It is however limited by **many uncertainty sources** to be detailed:

- the transport offer, i.e., the network structure, the roads capabilities, ...;
- the transport demand, provided as a dynamic origin–destination matrix;
- the behavior model explaining the users choices;
- the traffic assignment itself;
- the computation of the associated emissions.

The uncertainties in the inputs can be propagated using Monte Carlo simulations. The other sources of uncertainty should be addressed with the use of different model formulations.

The resulting ensemble of simulations needs to be calibrated using observations, so that the spread of the simulations represents the actual uncertainty of the models. The **calibration** should rely on **ensemble and probabilistic scores** that allow to evaluate ensemble simulations with observations. Specific developements on these scores are needed, especially to take into account the partial redundancy in observations. Promising approaches rely on **Bayesian inference**, with Markov chain Monte Carlo and model reduction. Because of the computational burden of uncertainty quantification, model reduction may be a key point, involving **dimension reduction** and **statistical emulation** (Gaussian processes).

It is expected that the PhD student makes generic contributions applicable to many fields where uncertain computationally-intensive models are used (e.g., in many environmental sciences). In particular, in the context of the project ESTIMAIR, the work will be the base for uncertainty quantification in the air quality model; hence the research results will be central in ESTIMAIR.

3 Working environment

The PhD student will be hosted by the "Teaching and Research Center in Atmospheric Environment" (CEREA) which is a joint laboratory between École des Ponts ParisTech and EDF R&D. The student will also join the Inria project-team Clime that works on data assimilation and uncertainty quantification for environmental problems. He or she will work under the supervision of Vivien Mallet (INRIA and CEREA) whose is leading the project ESTIMAIR, and Vincent Aguiléra (CEREMA and associated to the laboratory LVMT at École des Ponts ParisTech) who developed the model LADTA.

4 Additional information and contact

PhD position starting: about October 2014
Duration: 3 years
Salary: 1610 euros net per month
Location: École des Ponts ParisTech, in CEREA offices, which are in Marne-la-Vallée and accessible by train from Paris center in about 30 minutes
Contact:

- Vivien.Mallet@inria.fr — +33 1 39 63 55 76
- Vincent.Aguilera@enpc.fr — +33 1 60 52 31 32